AFCRL-69-0090

A FORTRAN PROGRAM TO GENERATE TIME VS. SOLAR DEPRESSION TABLES

by
Allan R. Zeiner

NORTHEASTERN UNIVERSITY
Boston, Massachusetts 02115

Contract No. AF 19(628)-5731

Project No. 7661
Task No. 766102
Work Unit No. 76610201

SCIENTIFIC REPORT NO. 1
January 31, 1969

Contract Monitor: Sam Silverman
Aeronomy Laboratory

Prepared
for

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS 01730

28

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Abstract

A program is presented for the generation of tables of solar depression versus time on a particular day or period of days for any location. The input data required are two values for each day and the value of ΔT for the year as taken from "The American Ephemeris and Nautical Almanac," the longitude and latitude of the location of interest, the maximum and minimum zenith angle desired. The program is suitable for or easily adapted to any first generation or newer computer capable of being programmed in Fortran.

Table of Contents

I. Introduction

The tabulated values of solar depression versus time currently available are of questionable value when used as a common denominator in the reduction of data gathered during atmospheric observations. In most cases, the discrete intervals of depression angle, day number and latitude are too widely spaced to allow for an accurate interpolation between given values. The accurate calculation of the time associated with a given depression angle, at a specific location, on a particular day or period of days has, up to now, been a laborious task. The program presented in this report has been developed to allow the generation of useful tables for any location. The input data required are two values for each day and the value of ΔT for the year as taken from "The American Ephemeris and Nautical Almanac" which is published in advance for any year, the longitude and latitude of the location of interest, the maximum and minimum zenith angles of interest and the increment desired between the given zenith angles.

II. Program Explanation

The basic method employed for computation is that illustrated in section 13.D of the "Explanatory Supplement to the Astronomical Ephemeris and Nautical Almanac." As can be seen upon checking the sample calculations, reproduced in Appendix E, the accuracy of this method is greatly influenced by the selection of the time used for the interpolation of the tabulated values of apparent declination and ephemeris transit. These tabulated values are taken from the Sun data for "0" hours ephemeris time as given in "The American Ephemeris and Nautical Almanac," hereafter abbreviated "AE and NA."

In order to achieve maximum accuracy, a reiterative method of calculation is used based upon the Newton Forward method of interpolation. An approximate time, used as an interpolation factor is inserted and with this, a calculated time for the zenith angle of interest is generated. This calculated time is then compared with the approximate time inserted, and unless the difference between the two is less than a specified tolerance, (0.0001 hours), the approximate time is replaced by the calculated time and the procedure repeated until the tolerance condition is met. Note that this leaves us with a value of ephemeris time for the angle of interest. The value of ΔT is now subtracted from the final calculated time to yield Greenwich mean time at the Greenwich meridian. To this value is added the value of West Longitude, converted to hours to finally yield the local Greenwich mean associated with the particular zenith angle. The program next increments to the next desired solar angle, and the procedure repeated until all desired angles for a given day are computed. Following this, the data for the next day are read in, and the calculations are repeated.

The zenith angle used to calculate sunrise and sunset is 90°, zero degrees horizon angle, rather than 90° 50' as used in the Explanatory Supplement to the "AE and NA." This angle was chosen because the primary interest was in the center point of the sun's disk rather than the upper limb; therefore, the semi-diameter of 16' was neglected. The horizontal refraction of 34' was neglected because our interest was in the effect of the sun upon the upper atmosphere.

The horizon angles that are tabulated in the output are those for points at sea level. Since our interest was in zenith atmospheric measurements only, this suited our purpose. If, however, the altitude of the observing location is to be taken into consideration, the zenith maximum and minimum angles may be increased by a factor of $1.17h^{1/2}$, where h is measured in feet.

The basic formula used for computation is:

$$\cos(h) = -\tan(\delta)\tan(\varphi) + \cos(z)\cos(\delta)\sec(\varphi)$$

where φ is the latitude of interest,

δ is the apparent declination of the sun at the time of interest,

z is the desired angle of the sun as measured from zenith,

and h is the local hour angle of the sun.

In temperate latitudes, no check normally need be made of the value of h calculated. When dealing with latitudes greater than 60°, however, and when the zenith angles of interest are 90° to 108°, there are days of the year when these angles do not actually occur; that is, these zenith angles are not reached. In the generation of the tables, these angles are inserted in the basic formula as a value for (z), resulting in a computed value of (h) which is also in error. Therefore, the time computed is also in error. This possibility has been considered, and the program will reject all erroneous times that are calculated due to the insertion of an angle that is not physically realizable, and insert a series of dash marks in the space ordinarily occupied by the time. See Appendix D for a sample output page which gives twilight information for Thule, Greenland, on September 10, 1968.

III. Use of the Program

This section is intended to provide all the information necessary to apply this program to any first generation or newer computer capable of being programmed in Fortran. However, the input and output statements used in the program as listed in Appendix B may have to be modified to allow its use on any specific computer. The body of the program may be used as listed.

Input data and format

The information given below is in the order that it necessarily must be placed

in a data deck. We will consider as an example the generation of a set of tables for the months of September and October, 1968, at a location of 58° 40' latitude and 42° 33' longitude. We desire the times associated with the horizon angles from -18° to 0° in $1/2^{\circ}$ increments. This would correspond to zenith angles of 108° to 90°.

Card 1. Longitude and latitude, with west longitude and north latitude being taken as positive.

Enter the data with input format (2F9, 4). Example,

; : 42.5500: : 58.6667, where ":" indicates a space.

Card 2. Increment between tabulated angles, maximum zenith angle, minimum zenith angle, and value of ΔT as taken from the "AE and NA"

Enter the data with the input format (F4.1, 2F5.0, F9.4)

Example, :0.5:108.: :90.:37.0000

Card 3. Month

Enter the month number, 1 thru 12, with the input format (I2).

Example, :9.

Cards 4^{+}. Day of month, apparent declination in degrees, minutes, and seconds, and ephemeris transit in hours, minutes, and seconds.

Enter the data with the input format (I2, I5, I3, F5.1, 2I3, F6.2).

Example, :1 : : :18 : : 3:53.4:12 : : 6:13.83.

```
22        0 22 50.7 11 52 38.89
23        0-30-31.8 11 52 18.00
24        0-23-55.2 11 51 57.23
25        0-47-18.9 11 51 36.60
26       -1 10 42.7 11 51 16.14

34       -4 177 9.8 11 48 40.48
50
10
 1       -3  7 29.0 11 49 36.86

35      -15 1942.5 11 43 36.51
99
```

Notice that there are four more days data than there are days in the month. These extra days are the first four days of the following month and are necessary for accurate interpolation of the input values of apparent declination and ephemeris transit.

Notice also the manner in which the sign of the apparent declination data changes. Unless the degrees term is an integer other than zero when the minutes and seconds are negative, the minutes and seconds terms must be given the minus sign.

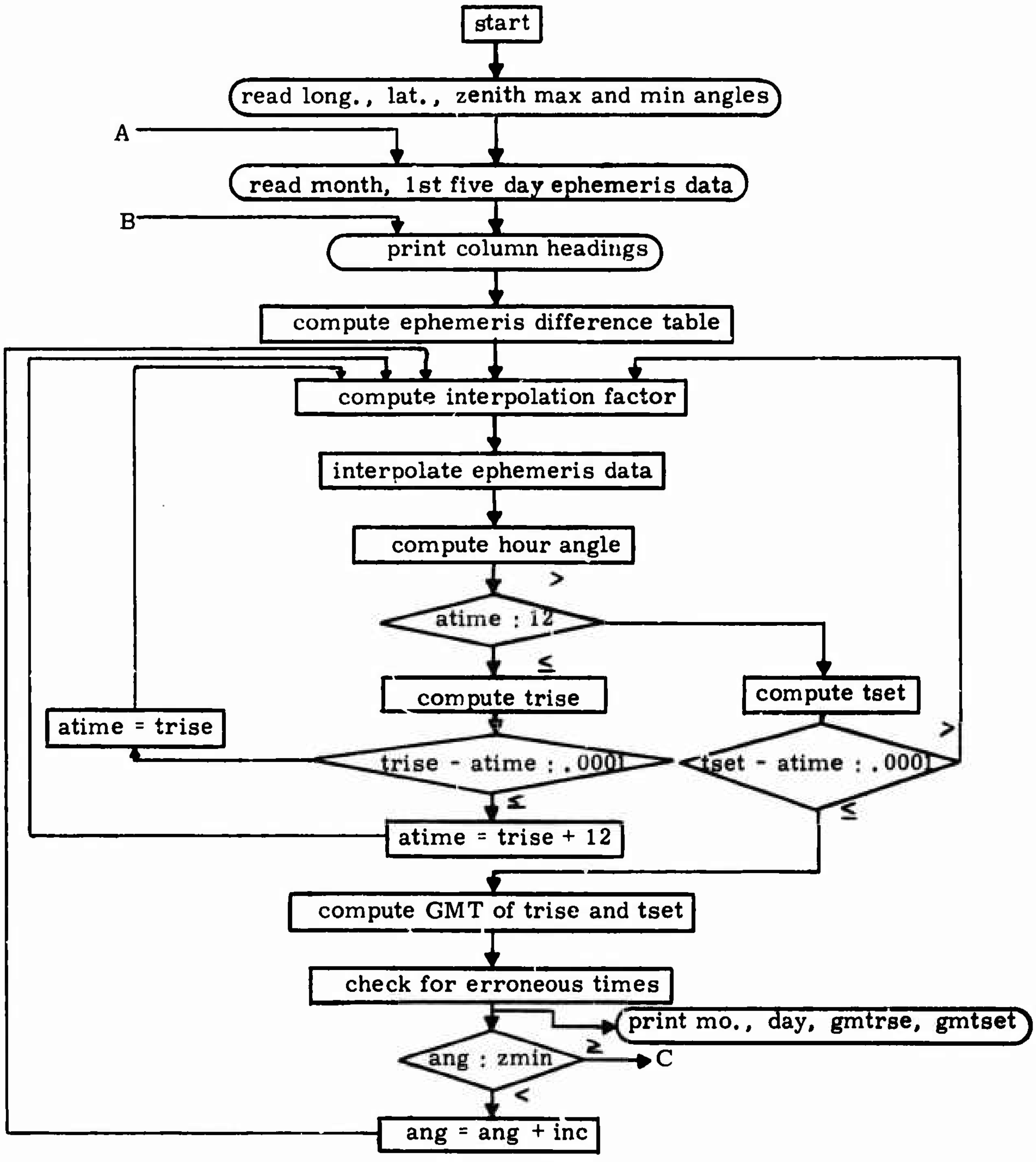
Control

If tables are to be generated for several months during the same computer run, the last entry is the day number column for all months except the last must be 50, followed by the next month's data. This allows the following month's data to be fed in automatically. To stop the program at the end of the last month's data, enter a 99 in the day number column using the same format as the day number, (I2). See Appendix C and the example given in the directions for cards 4^{+}.

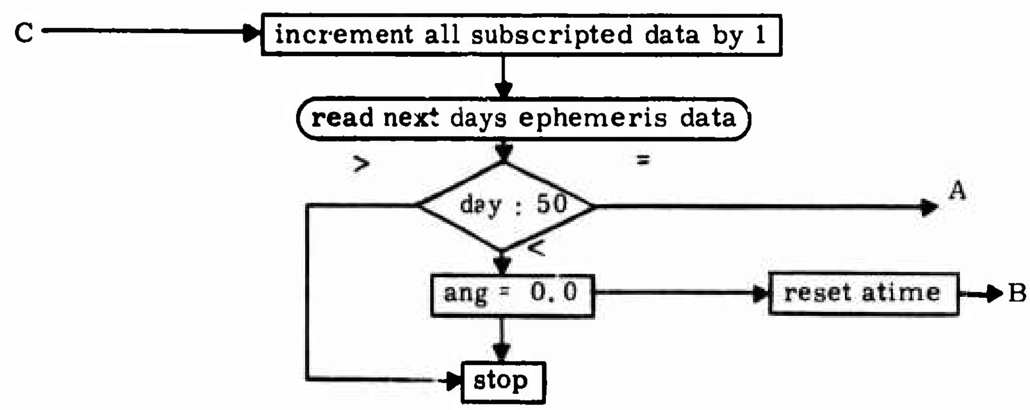
It should be obvious that there is no need to generate a whole month's table if the information is needed only for a small number of days. For example, if the period of interest were from Sept. 8 to Sept. 10, 1968, it would be necessary only to insert ephemeris data for Sept. 8 to Sept. 14, 1968. As explained previously, the extra four days data are used for the purposes of interpolation.

Appendix A

Program Flow Chart



Program Flow Chart (continued)



Appendix B

Program

```
      DIMENSION IAD1(5), IAD2(5), AD3(5), APD(5), AD1 (5), AD2(5)
      DIMENSION IER1(5), IER2(5), ER3(5), ETR(5), ER1 (5), ER2(5)
      DIMENSION DAPD1 (4), DAPD2(3), DAPD3(2), IDY(5)
      DIMENSION DETR1 (4), DETR2(3), DETR3(2)
c     THE LONGITUDE AND LATITUDE ARE NOW READ IN.
      READ 7, ALONG, ALAT
7     FORMAT (2F9.4)
c     THE ANGLE INCREMENT, ZENITH MAXIMUM AND MINIMUM
c     ANGLE AND VALUE OF DELTA T ARE NOW READ IN.
      READ 9, AINC, ZANGMX, ZANGMN, DELTAT
9     FORMAT (F4.1, 2F5.0, F9.4)
c     DEGREE TO RADIAN CONVERSION FACTORS AND INITIAL
c     VALUE OF APPROXIMATE TIME ARE COMPUTED.
      ZANGMX = ZANGMX + AINC
      DTOR = 3.1415926/180.
      RTOD = 180./3.1415926
      ATIME = 6.00
c     THE MONTH NUMBER AND THE FIRST FIVE DAYS
c     DATA ARE READ IN, TRIG. CONSTANTS COMPUTED,
c     AND OUTPUT HEADINGS PRINTED.
911   READ 912, MO
912   FORMAT(I2)
      DO 11  I = 1,5
11    READ 10, IDY(I), IAD1 (I), IAD2(I), AD3(I), IER1 (I), IER2(I), ER3(I)
10    FORMAT (I2, I5, I3, F5.1, 2I3, F6.2)
      ALATRD = ALAT*DTOR
      A = (SINF (ALATRD))/ (COSF (ALATRD))
      E = 1./COSF (ALATRD)
111   PRINT 890, ALONG, ALAT
890   FORMAT (1H1, 9HLOCATION, 5X, 9HLONGITUDE, F11.4,5X,
     1 8HLATITUDE, F11.4)
      PRINT 891
891   FORMAT (10X)
      PRINT 363
```

Program (continued)

```
363       FORMAT (1X, 5HMONTH, 2X, 3HDAY, 4X, 7HHORIZON, 5X,
     1    7HMORNING, 13X, 7HEVENING)
          PRINT 365
365       FORMAT (15X, 5HANGLE, 7X, 11HHR MIN SEC, 9X, 11HHR MIN SEC)
          PRINT 366
366       FORMAT (/)
          ANG = 0.0
          SPACER = 1.0
c         ALL DATA IN MINUTES AND SECONDS ARE CONVERTED
c         TO FRACTIONS OF HOURS OR DEGREES AND A DIFFERENCE
c         TABLE IS COMPUTED.
12        DO 21  J = 1,5
          AD1 (J) = IAD1 (J)
          AD2 (J) = IAD2 (J)
          ER1 (J) = IER1 (J)
          ER2 (J) = IER2 (J)
          IF (AD1(J) ) 18, 20, 20
18        APD (J) = AD1 (J) - (AD2 (J)/60.) - (AD3 (J)/3600.)
          GO TO 21
20        APD(J) = AD1(J) + (AD2(J)/60.) + (AD3(J)/3600.)
21        ETR(J) = ER1(J) + (ER2(J)/60.) + (ER3(J)/3600.)
          DO 26  K = 1,4
          DAPD1 (K)= APD (K+1) - APD (K)
26        DETR1 (K) = ETR (K+1) -ETR (K)
          DO 30 L = 1, 3
          DAPD2(L) = DAPD1(L+1) - DAPD1(L)
30        DETR2(L) = DETR1(L+1) - DETR1(L)
          DO 34 M = 1,2
          DAPD3(M) = DAPD2(M+1) - DAPD2(M)
34        DETR3(M) = DETR2(M+1) - DETR2(M)
          DAPD4 = DAPD3(2) - DAPD3(1)
          DETR4 = DETR3(2) - DETR3(1)
          D = ZAMGMZ*DTOR
c         AN INTERPOLATION FACTOR IS COMPUTED AND WITH
c         IT THE APPARENT DECLINATION AND EPHEMERIS TRANSIT
c         CORRESPONDING TO THE APPROXIMATE TIME ARE COMPUTED
38        B = ATIME/24. + 1.
          B1 = B-1.
          B2 = B-2.
```

```
             B3 = B-3.
             B4 = B-4.
             ITLE = 0
             ITLF = 0
             AD = APD(1) + DAPD1(1)*B1 + DAPD2(1)*B1*B2/2.
      1      +DAPD3(1)*B1*B2*B3/6. + DAPD4*B1*B2*B3*B4/24.
             ET = ETR(1) + DETR1(1)*B1 + DETR2(1)*B1*B2/2.
      1      +DETR3(1)*B1*B2*B3/6. + DETR4*B1B2*B3*B4/24.
c            USING THE VALUES OF APPARENT DECLINATION AND EPHEMERIS
c            TRANSIT COMPUTED BY INTERPOLATION, THE LOCAL HOUR
c            ANGLE IS COMPUTED AND CONVERTED TO AN EQUIVALENT TIME.
             ADRAD = AD*DTOR
             C = (SINF (ADRAD))/(COSF (ADRAD))
             FE = 1./COSF (ADRAD)
             G = COSF (D)
             HCOS = -A*C+E*FE*G
             O = HCOS**2
             X = ABSF (1.-O)
             HSIN = SQRTF (X)
             ABHCOS = ABSF (HCOS)
             HRAD = ATANF (HTAN)
             IF (HCOS) 59, 61, 61
59           HDEGRE = 180. - HRAD*RTOD
             GO TO 62
61           HDEGRE = HRAD*RTOD
62           HTIME = HDEGRE/15.
c            IT IS NEXT DETERMINED WHETHER THE APPROXIMATE TIME
c            USED CORRESPONDS TO A RISING OR SETTING ANGLE AND
c            IF THE TOLERANCE CONDITIONS IS MET.  IF NOT, THE
c            APPROXIMATE TIME IS REPLACED BY THE COMPUTED TIME AND
c            THE ENTIRE PROCESS REPEATED UNTIL THE TOLERANCE
c            CONDITION IS MET.
             IF(12. -ATIME) 70, 63, 63
63           TRISE = ET-HTIME
             ABTIME = ABSF(TRISE - ATIME)
             IF(.0001 - ABTIME) 66, 68, 68
66           ATIME = TRISE
             GO TO 38
68           IF (ANG) 661, 661, 663
```

```
661         ATIME1 = ATIME
663         ATIME = TRISE + 12.
            GO TO 38
70          TSET = ET + HTIME
            ACTIME = ABSF (TSET - ATIME)
            IF (.0001 - ACTIME) 73, 75, 75
73          ATIME = TSET
            GO TO 38
c           THE COMPUTED TIMES ARE CONVERTED TO GMT AND BROKEN
c           DOWN INTO HOURS, MINUTES AND SECONDS. NEXT A
c           CHECK IS MADE OF THE VALIDITY OF THE TIMES COMPUTED,
c           AN APPROPRIATE OUTPUT FORMAT STATEMENT SELECTED
c           AND THE TIMES PRINTED.
75          GMTRSE = TRISE = ALONG/15. - DELTAT/3600.
            GMTSET = TSET + ALONG/15. - DELTAT/3600.
            IF(24. - GMTSET) 744, 745, 745
744         GMTSET = GMTSET-24.
745         ITRISE = GMTRSE
            ATRISE = ITRISE
            BTRISE = GMTRSE - ATRISE
            BTRISE = BTRISE*60.
            IBTRSE = BTRISE
            BTRSE = IBTRSE
            CTRISE = (BTRISE - BTRSE)*60.
            ITSET = GMTSET
            ATSET = ITSET
            BTSET = GMTSET - ATSET
            BSET = BTSET*60.
            IBSET = BSET
            ABSET = IBSET
            CTSET = (BSET - ABSET)*60.
            IDAY = IDY(1)
            SPACER = SPACER + 1.0
            IF (2.0 - SPACER) 779, 779, 800
779         SPACER = 0.0
            PRINT 780
780         FORMAT (10X)
800         EDEP = (ZANGMX - ANG) -90.
            ADEP = 90.-(ZANGMX - ANG)
```

```
          IF(ANG-(AINC/2.)) 200, 201, 201
201       IF(TRISE - TRISE1) 202, 203, 203
202       ITLE = 5
203       IF(TSET1 - TSET) 204, 205, 205
204       ITLF = 10
205       IF(ITLE + ITLF)806, 806, 807
806       PRINT 90, MO, IDAY, ADEP, ITRISE,
     1    IBTRSE, CTRISE, ITSET, IBSET, CTSET
90        FORMAT (1X, 2(2X, I3) F8.1, 5X 2I4, F6.1, 6X, 2I4, F6.1)
          GO TO 200
807       IF ((ITLE + ITLF) -5) 200, 808, 810
808       PRINT 809, MO, IDAY, ADEP, ITSET, IBSET, CTSET
809       FORMAT (1X, 2(2X, I3), F8.1, 7X, 12H--  --  ----,2I4, F6.1)
          GO TO 200
810       IF ((ITLE + ITLF)-10) 200, 811, 813
811       PRINT 812, MO, IDAY, ADEP, ITRISE, IBTRSE, CTRISE
812       FORMAT (1X, 2(2X, I3), F8.1, 5X, 2I4, F6.1, 8X, 12H--  --  ----)
          GOTO 200
813       IF ((ITLE + ITLF)-15) 200, 814, 814
814       PRINT 815, MO, IDAY, ADEP
815       FORMAT (1X, 2(2X, I3), F8.1, 7X, 12H--  --  ----,
     1    8X, 12H--  --  ----)
c         NEXT I T IS DETERMINED IF ALL THE ANGLES FOR THE DAY
c         HAVE BEEN COMPUTED. IF NOT, THE PROGRAM INCREMENTS
c         TO THE NEXT ONE AND THE TIMES ARE COMPUTED.
c         IF ALL THE ANGLES FOR THE DAY HAVE BEEN COMPUTED,
c         THE PROGRAM INCREMENTS TO THE NEXT DAYS DATA
c         AND CONTINUES AS BEFORE.
200       TRISE1 = TRISE
          TSET1 = TSET
91        IF (ZANGMN - (EDEP + 90.))92, 95, 95
92        D = D-AINC*DTOR
930       ANG = ANG + AINC
          ATIME = TRISE
          GO TO 38
95        ATIME = TRISE
          DO 102 J 1,4
          IDY(J) = IDY(J+1)
          IAD1(J) = IAD1 (J+1)
```

Program (continued)

```
        IAD2(J) = IAD2(J+1)
        AD3(J) = AD3(J+1)
        IER1(J) = IER1(J+1)
        IER2(J) = IER2(J+1)
102     ER3(J) = ER3(J+1)
        READ 10, IDY(5), IAD1(5), IAD2(5), AD3(5 ), IER1(5), IER2(5), ER3(5)
        IF (IDY(5) - 50) 104, 125, 126
104     SPACER = -1.0
        GO TO 111
125     GO TO 911
126     STOP
        END
```

Appendix C

Sample Ephemeris Input Data

9

1	8	20	35.3	11	59	54.60
2	7	58	46.8	11	59	35.40
3	7	36	50.7	11	59	15.92
4	7	14	47.4	11	58	56.17
5	6	52	37.1	11	58	36.17
6	6	30	20.2	11	58	15.94
7	6	7	56.9	11	57	55.51
8	5	45	27.6	11	57	34.90
9	5	22	52.4	11	57	14.12
10	5	0	11.8	11	56	53.21
11	4	37	25.9	11	56	32.18
12	4	14	35.2	11	56	11.05
13	3	51	39.9	11	55	49.85
14	3	28	40.3	11	55	28.60
15	3	5	36.8	11	55	7.30
16	2	42	29.7	11	54	46.00
17	2	19	19.3	11	54	24.69
18	1	56	6.0	11	54	3.41
19	1	32	50.2	11	53	42.18
20	1	9	32.1	11	53	21.00
21	0	46	12.2	11	52	59.90
22	0	22	50.7	11	52	38.89
23	0	0	-31.8	11	52	18.00
24	0	-23	-55.2	11	51	57.23
25	0	-47	-18.9	11	51	36.60
26	-1	10	42.7	11	51	16.14
27	-1	34	6.1	11	50	55.85
28	-1	57	28.8	11	50	35.76
29	-2	20	50.5	11	50	15.88
30	-2	44	10.6	11	49	56.24
31	-3	7	29.0	11	49	36.86
32	-3	30	45.2	11	49	17.76
33	-3	53	58.9	11	48	58.96
34	-4	17	9.8	11	48	40.48

50

Sample Ephemeris Input Data (continued)

10						
1	-3	7	29.0	11	49	36.86
2	-3	30	45.2	11	49	17.76
3	-3	53	58.9	11	48	58.96
4	-4	17	9.8	11	48	40.48
5	-4	40	17.5	11	48	22.35
6	-5	3	21.8	11	48	4.60
7	-5	26	22.2	11	47	47.24
8	-5	49	18.6	11	47	30.29
9	-6	12	10.4	11	47	13.79
10	-6	34	57.5	11	46	57.75
11	-6	57	39.4	11	46	42.20
12	-7	20	15.8	11	46	27.14
13	-7	42	46.3	11	46	12.62
14	-8	5	10.5	11	45	58.63
15	-8	27	28.1	11	45	45.21
16	-8	49	38.7	11	45	32.37
17	-9	11	41.9	11	45	20.13
18	-9	33	37.2	11	45	9.50
19	-9	55	24.4	11	44	57.50
20	-10	17	2.9	11	44	47.14
21	-10	38	32.4	11	44	37.45
22	-10	59	52.4	11	44	28.41
23	-11	21	2.6	11	44	20.06
24	-11	42	2.4	11	44	12.39
25	-12	2	51.6	11	44	5.43
26	-12	23	29.6	11	43	59.17
27	-12	43	56.1	11	43	53.62
28	-13	4	10.5	11	43	48.81
29	-13	24	12.6	11	43	44.73
30	-13	44	1.8	11	43	41.41
31	-14	3	37.9	11	43	38.85
32	-14	23	0.3	11	43	37.07
33	-14	42	8.8	11	43	36.08
34	-15	1	3.0	11	43	35.89
35	-15	19	42.5	11	43	36.51
99						

Appendix D

Sample Output

Location,		Longitude	68.6667			Latitude	76.5500	
Month	Day	Horizon Angle	Morning Hr	Min	Sec	Evening Hr	Min	Sec
9	10	-18.0	--	--	---	--	--	---
9	10	-17.5	--	--	---	--	--	---
9	10	-17.0	--	--	---	--	--	---
9	10	-16.5	--	--	---	--	--	---
9	10	-16.0	--	--	---	--	--	---
9	10	-15.5	--	--	---	--	--	---
9	10	-15.0	--	--	---	--	--	---
9	10	-14.5	--	--	---	--	--	---
9	10	-14.0	--	--	---	--	--	---
9	10	-13.5	--	--	---	--	--	---
9	10	-13.0	--	--	---	--	--	---
9	10	-12.5	--	--	---	--	--	---
9	10	-12.0	--	--	---	--	--	---
9	10	-11.5	--	--	---	--	--	---
9	10	-11.0	--	--	---	--	--	---
9	10	-10.5	--	--	---	--	--	---
9	10	-10.0	--	--	---	--	--	---
9	10	-9.5	--	--	---	--	--	---
9	10	-9.0	--	--	---	--	--	---
9	10	-8.5	--	--	---	3	41	43.0
9	10	-8.0	5	31	50.9	3	11	30.1
9	10	-7.5	5	59	12.1	2	49	34.6
9	10	-7.0	6	20	3.4	2	31	20.3
9	10	-6.5	6	37	42.6	2	15	17.9
9	10	-6.0	6	53	22.8	2	0	45.1
9	10	-5.5	7	7	40.2	1	47	17.8
9	10	-5.0	7	20	56.4	1	34	40.9

Sample Output (continued)

Location		Longitude	68.6667			Latitude	76.5500	
Month	Day	Horizon Angle	Morning Hr	Min	Sec	Evening Hr	Min	Sec
9	10	-4.5	7	33	25.2	1	22	43.9
9	10	-4.0	7	45	16.0	1	11	19.4
9	10	-3.5	7	56	35.9	1	0	21.9
9	10	-3.0	8	7	30.0	0	49	47.1
9	10	-2.5	8	18	2.3	0	39	31.5
9	10	-2.0	8	28	16.1	0	29	32.4
9	10	-1.5	8	38	14.2	0	19	47.5
9	10	-1.0	8	47	58.5	0	10	15.0
9	10	-0.5	8	57	31.1	0	0	53.1
9	10	- 0	9	6	53.5	23	51	40.4

Appendix E

Sample Calculation

Reproduction of example from section 13.D of the Explanatory Supplement to the American Ephemeris and Nautical Almanac.

March 7, 1960 Latitude 52°

$\Phi = 52^{\circ}$ tan Φ = 1.2799 sec Φ = 1.6243

	Morning Twilight	Sunrise	Sunset	Evening Twilight
Approx. time	$4^h\ 30^m$	$6^h\ 30^m$	$18^h\ 00^m$	$19^h\ 30^m$
δ (A.E., pg 21)	$-5^{\circ}\ 17'$	$-5^{\circ}\ 15'$	$-5^{\circ}\ 04'$	$-5^{\circ}\ 02'$
tangent δ	-0.0925	-0.0919	-0.0887	-0.0881
secant δ	1.0043	1.0042	1.0039	1.0039
z	108°	$90^{\circ}\ 50'$	$90^{\circ}\ 50'$	108°
cosine z	-0.3000	-0.0145	-0.0145	-0.3090
-tan Φ tan δ	0.1184	0.1176	0.1135	0.1128
cos z sec Φ sec δ	-0.5041	-0.0237	-0.0237	-0.5039
cosine h	-0.3857	-0.0939	0.0898	-0.3911
	h min	h min	h min	h min
h	7 30.7	5 38.5	5 39.4	7 32.1
ephemeris transit	12 11.2	12 11.2	12 11.0	12 11.0
Time (local)	4 40.5	6 32.7	17 50.4	19 43.1

Appendix F

Glossary of Terms

IAD1	apparent declination, degrees (fixed point)
IAD2	apparent declination, minutes (fixed point)
AD3	apparent declination, seconds
APD	apparent declination, degrees and decimals of degrees
AD1	apparent declination , degrees (floating point)
AD2	apparent declination, minutes (floation point)
IER1	ephemeris transit, hours (fixed point)
IER2	ephemeris transit, minutes (fixed point)
ER3	ephemeris transit, seconds
ETR	ephemeris transit, hours and decimals of hours
ER1	ephemeris transit, hours (floating point)
ER2	ephemeris transit, minutes (floating point)
DAPD1	apparent declination, first difference
DAPD2	apparent declination, second difference
DAPD3	apparent declination, third difference
DAPD4	apparent declination, fourth difference
DETR1	ephemeris transit, first difference
DETR2	ephemeris transit, second difference
DETR3	ephemeris transit, third difference
DETR4	ephemeris transit, fourth difference
IDY	day number
ALONG	longitude
ALAT	latitude
AINC	degree increment
ZANGMX	maximum zenith angle
ZANGMN	minimum zenith angle
DELTAT	correction factor, ephemeris time to universal time
DTOR	conversion factor, degrees to radians
RTOD	conversion factor, radians to degrees
ATIME	approximate time
MO	month
ALATRD	latitude in radians
A	tangent (latitude)
E	secant (latitude)
ANG	counter for angle increment

Glossary of Terms (continued)

SPACER	counter to control output spacing
D	zenith angle in radians
B	interpolation factor
B1 TO B4	interpolation factors
ITLE	error check counter
ITLF	error check counter
AD	apparent declination after interpolation
ET	ephemeris transit after interpolation
ADRAD	apparent declination in radians
C	tangent (apparent declination)
FE	secant (apparent declination)
G	cosine (zenith angle)
HCOS	cosine of hour angle
HSIN	sine of hour angle
ABHCOS	absolute value of the cosine of the hour angle
HTAN	tangent of hour angle
HRAD	hour angle in radians
HDEGRE	hour angle in degrees
HTIME	time corresponding to hour angle of H
TRISE	local time of zenith angle during AM
ABTIME	absolute value of local time during AM
TSET	local time of zenith angle during PM
ACTIME	absolute value of local time during PM
GMTRSE	GMT of hour angle during AM
GMTSET	GMT of hour angle during PM
ITRISE	hour of AM zenith angle (fixed point)
ATRISE	hour of AM zenith angle (floating point)
BTRISE	minutes of AM zenith angle (floating point)
IBTRSE	minutes of AM zenith angle (fixed point)
BTRSE	minutes of AM zenith angle (floating point)
CTRISE	seconds of AM zenith angle (fixed point)
ITSET	hours of PM zenith angle (fixed point)
ATSET	hours of PM zenith angle (floating point)
BTSET	minutes of PM zenith angle (floating point)
IBSET	minutes of PM zenith angle (fixed point)
BSET	minutes of PM zenith angle (floating point)
ABSET	minutes of PM zenith angle (floating point)
CTSET	seconds of PM zenith angle (floating point)

Glossary of Terms (continued)

IDAY	day for printout
EDEP	counter for zenith angle
ADEP	counter for zenith angle
TRISE1	ne of zenith angle AM
TSET1	time of zenith angle PM

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A program is presented for the generation of tables of solar depression versus time on a particular day or period of days for any location. The input data required are two values for each day and the value of ΔT for the year as taken from "The American Ephemeris and Nautical Almanac," the longitude and latitude of the location of interest, the maximum and minimum zenith angle desired. The program is suitable for or easily adapted to any first generation or newer computer capable of being programmed in Fortran.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Solar Depression Times						
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